PROSPECTS OF NANOTECHNOLOGY IN MEDICINE

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The concept of nanotechnology is firmly entering our lives, and back in 1959, the famous American theoretical physicist Richard Feynman said that there is "an amazingly complex world of small forms, and someday (for example, in 2000) people will be surprised that before 1960 no one took seriously the study of this world." At the first stage, the development of nanotechnology was determined mainly by the creation of probe microscopy devices. These devices are a kind of eyes and hands of the nanotechnologist.

Today, progress in the field of nanotechnology is associated with the development of nanomaterials for the aerospace, automotive, and electronic industries. But gradually, medicine is increasingly mentioned as a promising area of application of nanotechnology. This is due to the fact that modern technology allows us to work with matter on a scale that until recently seemed fantastic - micrometers, and even nanometers. These are the sizes that are typical for the main biological structures - cells, their components (organelles) and molecules. Today, we can talk about the emergence of a new direction - nanomedicine. The idea of \u200b\u200busing microscopic devices in medicine was first expressed in 1959 by R. Feynman in his famous lecture "There's Plenty of Room at the Bottom" (referring to the idea of Albert R. Hibbs). But only in the last few years have Feynman's proposals come closer to reality. Of course, today we can only make assumptions about the paths that science of the future will take, and medical science in particular. Some of these assumptions will be more substantiated, others less so. Thus, it is more or less safe to expect that modern methods will be further developed. For example, microdevices will become increasingly miniature and sophisticated, and their functions will become increasingly rich.

On the other hand, we can expect that unexpected turns will be encountered along this path. Some of the approaches that seem promising now will prove fruitless. Others that seem fantastic now may justify themselves; we will consider some of these "fantastic" approaches here. Most likely, some completely new ideas will arise. Three approaches to nanomedicine. Let us consider the methods by which diagnostics and treatment at the cellular, subcellular and molecular levels may be carried out in the future. Today, the proposed paths to this can be divided into three groups: The "Top-Down" Approach This is the approach that consists of further improvement of existing microdevices, primarily their further miniaturization. The idea of the "top-down" approach (as well as the idea of nanotechnology in general) was first consistently outlined in 1959 by R. Feynman. The use of modern microelectronic technology methods makes it possible to manufacture elements smaller than a micron. These methods can be extended beyond purely electronic technology. Examples include microelectromechanical systems (MEMS) and microfluidics - the control of fluid flows on a micron scale. Modern technology allows the production of many devices such as micromotors, accelerometers, gyroscopes, various microsensors, microvalves, micropumps and gear transmissions.

Currently, a number of groups of scientists around the world are working on creating microdevices that could operate inside the human body. Such devices can be permanently fixed in tissues, move passively - for example, along the gastrointestinal tract - or actively. In the latter case, they can "crawl" along the surfaces of the internal cavities of the human body, swim in internal fluids, or even "drill" passages in tissues. A project being developed at the University of Utah, USA, is a microsubmarine with an engine that uses the work of bacteria such as Salmonella typhimurium. These bacteria are capable of swimming in liquid; when attached to the rotor of the engine, they will be able to set in motion a shaft with a propeller fixed to it. To make an even more miniature device, not whole bacteria, but only their propeller flagella, could be used. The source of energy for such an engine could be oxygen and glucose, freely diffusing inside from the environment. Another similar project is being developed by MicroTEC from Duisburg, Germany. It uses an external alternating electromagnetic field as an energy source.

Devices of this kind, equipped with on-board control, communication and orientation systems based on nanotechnology, nanosensors and nanomanipulators, may become a reality in the foreseeable future.

The "Wet" Nanotechnology Approach. This approach is based on the use of ready-made mechanisms that exist in living nature. Perhaps, this idea was first formulated in 1967 by the American biochemist (and, concurrently, science fiction writer) Isaac Asimov. He was the first to suggest using mechanisms consisting of nucleic acid molecules and enzymes. A year later, White suggested using genetically modified viruses as mechanisms for cell repair.

In 1964, physicist Robert Ettinger proposed in his book "Prospects of Immortality" that freezing at ultra-low temperatures (cryonics) could be used to preserve the human body until advances in science would allow it to be defrosted, revived, and cured. Ettinger, well aware of the damage such freezing would cause at the cellular level, suggested that mechanisms capable of repairing such damage would be possible in the future. In 1972, Ettinger suggested that biorobots based on genetically modified existing microorganisms could be used to restore damaged cells.

Biotechnology. Using existing organisms as a basis for creating biorobots promises a number of advantages. The original organism provides ready-made systems for energy supply, reproduction, movement, self-repair, etc. There are proven methods for obtaining genetic modifications; experience in using microorganisms for various purposes. Of course, it will take years or even decades before it becomes possible to create a truly effective biorobot.

Virus as a robot. Currently, viruses are already actively used to introduce new genetic material into cells. In the future, one can imagine the use of various robot viruses capable of recognizing a cell of a certain type in a certain state. Depending on the specific situation, such a robot virus will be able to kill this cell (for example, a pathogen) or introduce the necessary DNA or RNA molecules into it - up to a complete replacement of the damaged genetic material.

Robot cell. Cells in the human body are capable of purposeful movement, sometimes over long distances, destroying other cells or, conversely, integrating into damaged tissues in place of dead ones. It is not so difficult to imagine cells artificially modified so that they destroy atherosclerotic plaques, regenerate damaged organs, limbs, etc. Cells can carry tags that allow their movement throughout the body to be monitored, and release substances into the environment that carry diagnostic information. Several types of cells can be mentioned that seem promising as the basis for a biorobot.

Firstly, these are various bacterial cells. They may have ready-made mechanisms for movement and even penetration into the cells of the host organism. The genetic apparatus of bacteria is quite easy to modify. They are capable of quite complex "behavior". They can produce a variety of proteins and other substances depending on the situation. Bacteria are even capable of coordinating their actions by releasing various signal substances into the environment. They can also transmit significant amounts of information by exchanging ring DNA molecules - plasmids. Bacterial genomes must be modified in such a way that they do not pose a danger to humans. Thus, bacteria can be deprived of the ability to reproduce in the organism itself; the required quantities will be obtained outside it under special conditions.

Secondly, these are human cells - such as fibroblasts. The advantage of fibroblasts is that they do not carry on their surface the so-called HLA antigens, which mainly determine the rejection of foreign tissues by the body's immune system.

Another type of cell that seems very promising is lymphocytes. There are several types of lymphocytes in the human body that perform different tasks within the framework of providing immune protection. Many of them are capable of very complex "behavior". It is possible that it will be possible to genetically modify a person's own (and therefore not rejected) lymphocytes so as to give them certain additional functions.

Methods of molecular biology. The human body contains a huge number of various enzymes (another name for them is enzymes). These are proteins or protein compounds with diverse and highly selective activity. Some of them perform extremely complex and important functions. First of all, this applies to those enzymes that, together with nucleic acids, ensure the operation of the genetic mechanism. As an example, let's consider the enzyme DNA reparase. Its molecule moves along the double helix of DNA and corrects errors in the sequence of nucleotides that make up this helix. Such errors inevitably occur under the influence of temperature, various chemicals, radiation, etc. The DNA reparase molecule finds a DNA molecule, moves along it, recognizes violations in the nucleotide sequence, decides which of the 2 DNA strands is considered correct, "fishes" the desired nucleotide from the environment, removes the incorrect one and inserts the correct one in its place. In practice, it behaves like a robot solving a rather complex and multivariate task of situational behavior.

It is far from clear how protein molecules are capable of such complex "behavior". Thus, it has been suggested that the DNA-enzyme complex is capable of working as a quantum computer. There is no way to confirm or refute this hypothesis yet. However, the very ability of protein molecules to complex "behavior" associated with information processing is an indisputable fact. It seems very tempting to try to modify existing proteins or synthesize new ones capable (possibly in combination with DNA carrying information and "programs") of solving other, including even more complex problems, such as the treatment of damaged or aged cells. It must be recognized, however, that we are still quite a long way from the necessary level of understanding the work of enzymes. A simpler way may be to use the ability of protein molecules and shorter polypeptides to selectively bind to each other and to molecules of other substances. This should allow self-assembly of such molecules into a predetermined supermolecular structure similar to the parts of a children's construction set. Another class of macromolecules that can be used for self-assembly are nucleic acids. There are two main types of nucleic acids.

Deoxyribonucleic acid (DNA) forms a very stable configuration of two strands woven into a double helix. DNA is the main carrier of genetic information in the cell. Sections of a DNA strand are capable of selectively binding to other strands that have a so-called complementary nucleotide sequence. It is by this principle that two DNA strands that are complementary to each other bind. But the binding of complementary sections allows different DNA strands to be connected to each other in a predictable way. At the same time, by changing the sequence of nucleotides in the strands, it is possible to select any predetermined configuration of their coupling. And here an analogy with a children's construction set comes to mind. Great success in this direction was achieved by Nadrian Ziman from New York University. He managed to fold many different flat and three-dimensional structures from DNA molecules - tetrahedrons, cubes, octahedrons, dodecahedrons, icosahedra, prisms and many others.

Drexler called the device (still hypothetical) for such assembly of nanomechanisms an assembler. Theoretically, an assembler can be very small - micron-sized. Since anything can be assembled from individual atoms, such an assembler can make a copy of itself. On the one hand, this opens the way to the production of an unlimited number of assemblers and - with their help - any other nanodevices . Such an approach can be used, for example, for terraforming planets - their global reconstruction in order to make them suitable for human habitation. On the other hand, there may be a danger of the assembler reproduction getting out of control as a result of accidental or deliberate damage to their control systems. Calculations show that, theoretically, such an assembler and its offspring will be able to process all of the Earth's biomass in a matter of hours (though without taking into account the time it takes to move across the planet's surface). This danger has been dubbed the "Grey goo problem". Preliminary analysis shows that the assembler can be made reliable enough that the probability of a self-reproducing error is negligible. However, it is difficult to exclude the possibility of deliberate programming of the assembler by a maniac or hooligan, similar to modern creators of computer viruses. Hypothetical nanodevices capable of moving in the environment and equipped with an on-board control system are called nanorobots. They can be used to solve a huge number of problems - diagnostics and treatment of any diseases, including aging, restructuring of the human body "on request", production of super-strong structures up to "Earth-orbit" elevators and even "Earth-Moon", terraforming other planets, etc.

The ideas of molecular nanotechnology also meet with strong opposition. The most prominent critic is the 1996 Nobel Prize laureate in chemistry Richard Smiley. In a series of press discussions with E. Drexler, Smiley acknowledged some of the points of molecular nanotechnology that he had previously criticized; some other disagreements can probably be resolved only by experiment.

Another open question is the nature of the influence of quantum mechanical effects on the functioning of molecular nanodevices. In modern models, parts are considered mainly as classical objects. It can be said that molecular nanotechnology is one of the most controversial, but also the most promising direction in modern science. The question of the feasibility of its ideas will probably be resolved in the coming petty years, and perhaps even earlier.

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